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AN EXPERIMENTAL INVESTIGATION ON UTILIZATION OF GROUND GRANULATED BLAST FURNACE SLAG AND WASTE FOUNDRY SAND AS A PARTIAL REPLACEMENT IN CONCRETE

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Abstract — The increased quest for sustainable and eco-friendly materials in the construction industry has led to research on partial replacement of the conventional constituents of concrete by two selected waste materials. The attempt is made on replacing Ground Granulated Blast-furnace Slag (GGBS) and Foundry sand as a partial replacement for cement and fine aggregate in concrete. In this project work, Ordinary Portland Cement (OPC) is replaced by 20, 40 & 60 percentage replacement of GGBS and 30% of fine aggregate is replaced by the Foundry sand in M_{25} grade concrete with High range water reducers. The compressive strength and split tensile strength of concrete mix at 7^{th}, 14^{th} and 28^{th} day of curing period is determined along with the workability property of fresh concrete and results are analysed and compared with the conventional mix.

Keywords- *Ground Granulated Blast-furnace Slag (GGBS), Foundry sand (FS)*

I INTRODUCTION

Concrete is a most essential requirement for the construction of various structures, but nowadays the various concrete making materials such as cement, river sand and coarse aggregate are over exploited which results in various environmental impacts such as deepening of river beds and the cement emits co_2 into the atmosphere which cause global warming. So the attempt is made to find out an eco-friendly substitute for the cement and fine aggregate by using ground granulated blast furnace slag and foundry sand. In this research work, the ordinary portland cement is replaced by 20, 40 & 60% of GGBS and 30% of the fine aggregate is replaced by the Foundry sand in M_{25} grade concrete with high range water reducers. Then their strength parameters are determined at 7^{th}, 14^{th}, 28^{th} days of curing and it is compared with the conventional concrete mix.

II MATERIALS USED

A. *Cement*

Cement is a binding material that sets and hardens independently, and can bind other materials together. It hardens and attains strength from chemical reaction with the water known as hydration. The grade 53 ordinary Portland cement is used for this research work.

B. *Fine Aggregate*

Normal dry river sand is used as a fine aggregate, the sand passing through IS 4.75mm sieve with fineness modulus of 2.87 and specific gravity of 2.62 is used as a fine aggregate.

C. *Coarse Aggregate*

Gravel of 20mm size is used as a coarse aggregate which have impact value of 37.6% and crushing value of 32.5%.

D. *GGBS*

GGBS is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

Fig. 1 *– GGBS*

E. *Foundry Sand*

Foundry sand is high quality silica sand with uniform physical characteristics. It is a by-product of ferrous and non-ferrous metal casting industries, where sand has been used for centuries as a moulding material because of its thermal conductivity. It is a by-product from the production of both ferrous and non-ferrous metal castings. The physical and chemical characteristics

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of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates.

Fig. 2 – Foundry Sand

III. MATERIAL PROPERTIES

A. *Property of cement and GGBS*

The property of the cement and GGBS is tabulated below,

Table I – Property of cement and GGBS

Property	Cement	GGBS
Fineness modulus	6%	3%
Consistency	32.5%	25%
Initial setting time	33mins	45mins
Final setting time	10 Hours	10Hours
Specific Gravity	3.11	2.86

B. *Property of river sand and foundry sand*

The property of the normal river sand and Foundry sand is tabulated below,

Table II – Property of river sand and foundry sand

Property	River Sand	Foundry Sand
Fineness modulus	2.87	2.66
Specific Gravity	2.62	2.30

C. *Property of Coarse aggregate*

The property of the coarse aggregate is tabulated below,

Table III – Property of coarse aggregate

Property	Coarse aggregate
Fineness Modulus	6.65
Impact value	37.60%
Crushing Value	32.24%

IV. TEST ON FRESH CONCRETE

A. *Slump cone test on fresh concrete*

Slump cone test is conducted on the fresh concrete , the workability of the different mixes having 30% of Foundry sand and 20%, 40% & 60% of GGBS is observed and it is compared with the workability of the conventional concrete mix. The results are tabulated below,

Table IV – Slump Cone test on fresh concrete

Percentage of replacement	Initial height (mm)	Final height (mm)	Slump value (mm)
Conventional Concrete	300	264	36
30% FS 20% GGBS	300	246	54
30% FS 40% GGBS	300	228	72
30% FS 60% GGBS	300	210	90

V. MATERIAL PROPORTIONING

A. *Cubes*

The material proportioning for one cube of size 150mm x 150mm is tabulated below for various mixes,

Table V – Material proportioning for cube

Percentage replaceme nt	Cemen t (Kg)	GGB S (kg)	FA (kg)	FS (kg)	CA (kg)
Convention al concrete	1.9075	-	1.907 5	-	3.815 1
30% FS 20% GGBS	1.526	0.381 5	1.335	0.57 3	3.815 1
30% FS 40% GGBS	1.1445	0.763	1.335	0.57 3	3.815 1
30% FS 60% GGBS	0.763	1.144 5	1.335	0.57 3	3.815 1

B. *Cylinders*

The material proportioning for one cylinder of diameter 150mm and height 300mm is tabulated below for various mixes,

Table VI – Material proportioning for cylinder

Percentage replacement	Cement (Kg)	GGBS (kg)	FA (kg)	FS (kg)	CA (kg)
Conventional concrete	2.99	-	2.99	-	5.98
30% FS 20% GGBS	2.392	0.598	2.093	0.897	5.98
30% FS 40% GGBS	1.794	1.196	2.093	0.897	5.98
30% FS 60% GGBS	1.196	1.794	2.093	0.897	5.98

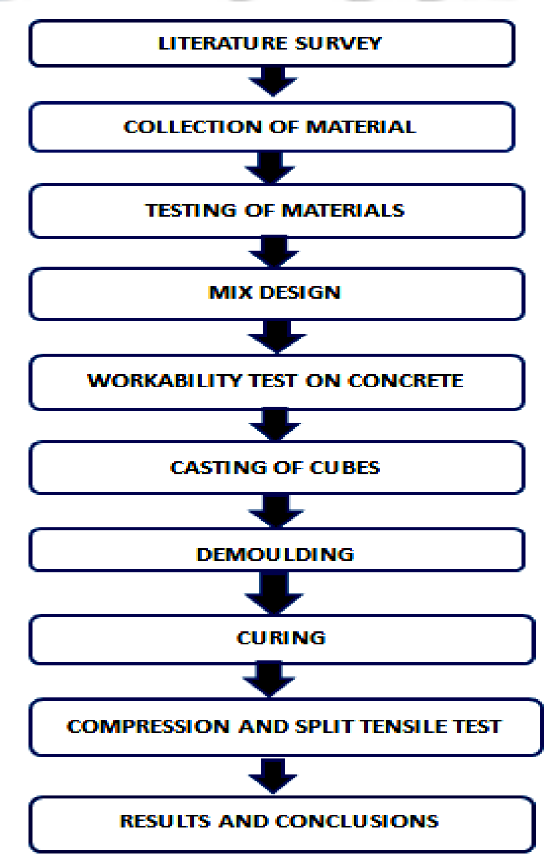

Fig.3 *– Project flow chart*

VI. TESTING OF SPECIMENS

Totally 36 cubes and 36 cylinders were prepared for the 7th, 14th & 28th day testing with 30% constant replacement of fine aggregate by foundry sand and 0%, 20%,40% & 60% of cement was replaced by GGBS.

Table VII – Specimens

Replacement Percentage	No of Cubes	No of Cylinders
Conventional Concrete	9	9
30% FS 20% GGBS	9	9
30% FS 40% GGBS	9	9
30% FS 60% GGBS	9	9

A. *Compression test on cubes*

The test is done on 7th, 14th, 28th day of curing to determine the compressive strength of concrete specimens as per IS: 516 – 1959. Three cubes are tested in each proportions and the average value of the three cubes are taken as their compressive strength. The compressive strength of the cube is determined by the following formula and expressed in terms of N/mm^2.

$$\text{Compressive strength} = \frac{\text{Maximum load}}{\text{Area}}$$

Table VIII *– Compressive strength of cubes*

Percentage of replacement	Compressive strength N/mm^2		
	At 7th day	At 14th day	At 28th day
Conventional Concrete	17.68	21.78	25.11
30% FS 20% GGBS	19.55	23.34	27.12
30% FS 40% GGBS	20.45	25.35	32
30% FS 60% GGBS	15.4	17.6	23.6

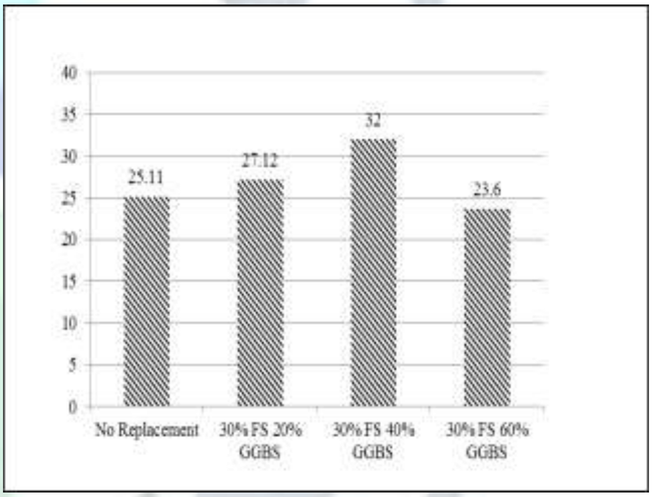

Fig.4 - Compressive Strength of cubes

B. *Split tensile test on cylinders*

The test is done on 7th, 14th, 28th day of curing to determine their split tensile strength. The specimens are placed horizontally between the loading surface of the Compression testing machine and the load is applied till the specimens fails. The ultimate load at the time of the failure is noted down.

Horizontal compressive strength $= 2p/\pi LD$
Where p is the compressive load
L is the length of the cylinder
D is the diameter of the cylinder

***Table IX** – Split tensile strength of cylinders*

Percentage of replacement	Tensile strength N/mm^2		
	7th day	14th day	28th day
Conventional Concrete	2.12	2.68	3.11
30% FS 20% GGBS	2.40	2.90	3.46
30% FS 40% GGBS	2.68	3.25	3.82
30% FS 60% GGBS	1.98	2.47	2.83

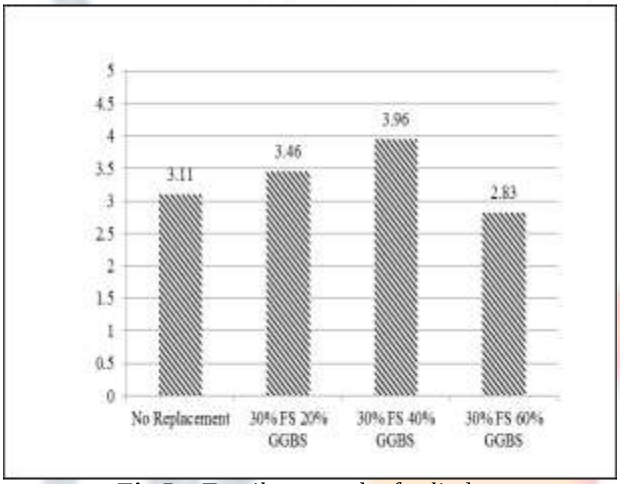

***Fig.5** – Tensile strength of cylinders*

VII. RESULTS AND DISCUSSIONS

From the results obtained from the various tests, the following conclusions were made,

- The fineness modulus of the GGBS is lower than the Ordinary Portland Cement, which makes the concrete denser and gives smooth finishes to the specimens.
- The workability of the concrete increases with the percentage of replacement of cement by GGBS increases, which is witnessed by the results of slump cone test.
- The compressive strength and split tensile strength of the cubes and cylinders increases when the 20% and 40% of cement is replaced by GGBS and 30% of fine aggregate is replaced by Foundry Sand. When the 60% of cement is replaced by GGBS with 30% of Foundry Sand, slight reduction in the compressive strength and split tensile strength is observed.
- 27.5% increment in the compressive strength is found at 40% replacement of cement by GGBS and 30% of fine aggregate by Foundry Sand at 28 days when compared to normal concrete. And the strength decreases by 6% when the cement is replaced by 60% of GGBS and fine aggregate is replaced by 30% of Foundry Sand.
- 18.5% increment in the split tensile strength is found at 40% replacement of cement by GGBS and 30% of fine aggregate by Foundry Sand at 28 days when compared to normal concrete. And the strength decreases by 9% when the cement is replaced by 60% of GGBS and fine aggregate is replaced by 30% of Foundry Sand.
- The 30% Foundry Sand and 40% GGBS is found to be the optimum percentage at which the cement and fine aggregate can be replaced.

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